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PHE-11

BACHELOR OF SCIENCE (B.Sc.)

Term-End Examination

01702

June, 2017

PHYSICS

PHE-11 : MODERN PHYSICS

Time : 2 hours *Maximum Marks : 50*

Note : *Attempt **all** questions. The marks for each question are indicated against it. The values of physical constants are given at the end. Symbols have their usual meanings.*

1. Answer any ***five*** parts : *5×3=15*

(a) The average lifetime of a π-meson at rest is 26 ns. The meson is moving with a speed of 0·9 c with respect to the Earth. Calculate its lifetime as measured by an observer at rest on the Earth.

(b) Show that in the limit $v << c$, the expression for the relativistic kinetic energy approaches the classical kinetic energy.

(c) Write down the probabilistic interpretation of the wave function.

(d) The lifetime of an excited state is 8 ns. If this is the uncertainty in photon emission, calculate the uncertainty in the frequency ($\Delta \nu$).

(e) Draw approximate energy levels for the L and K shells and show all the allowed transitions.

(f) State whether or not the following reactions are allowed :

(i) $n \rightarrow p + e + \bar{\nu}_e$

(ii) $\bar{\lambda}_0 \rightarrow p + \pi^-$

(g) List three applications of radioisotopes as tracers.

(h) The mean life of a radioactive element is 14 months. Calculate the time required for 75% of the element to decay.

2. Answer any *one* part : *1×10=10*

(a) (i) A particle moves with a uniform velocity $\vec{v}$ relative to the S-frame. Derive an expression for its velocity relative to a frame S′ which is moving with a uniform velocity $V\hat{i}$ relative to the S-frame.

(ii) A person on the moon observes two spaceships moving towards him from opposite directions at speeds of 0·7 c and 0·8 c, respectively. Calculate the relative speed of the two spaceships as measured by an observer on either one. *6+4*

(b) (i) Using the expression for the relativistic linear momentum of a particle and the mass-energy equivalence, derive an expression relating the energy and momentum of a relativistic free particle.

(ii) Calculate the potential difference through which a proton must be accelerated to achieve a speed of 0·6 c. (Rest mass of the proton is 938 MeV) *6+4*

3. Answer any ***two*** parts : *2×5=10*

(a) In a region of space, a particle with mass m and zero energy has a time independent wave function :

$$\Psi(x) = A\, x\, e^{-x^2/L^2}$$

where A and L are constants. Use the Schrödinger equation to determine the potential energy of the particle.

(b) A photon and an electron each have an energy of $6 \cdot 0 \times 10^3$ eV. Calculate their respective wavelengths. Which of these could be used to probe atomic structures ? Explain.

(c) Prove the Ehrenfest theorem for the position operator :

$$\frac{d < x >}{dt} = \frac{1}{m} < p_x >$$

4. Answer any ***one*** part : *1×10=10*

(a) Write down the Schrödinger equation for a one-dimensional harmonic oscillator with an angular frequency ω. Calculate the mean potential energy of a simple harmonic oscillator in its ground state :

$$\Psi_0(x) = \left(\frac{a}{\sqrt{\pi}}\right)^{1/2} \exp\left(\frac{-a^2 x^2}{2}\right)$$

where $a^2 = \frac{m\omega}{\hbar}$.

What is the energy eigenvalue of the ground state ? Is the ground state of even parity or odd parity ? *2+6+1+1*

(b) (i) Write down the time independent Schrödinger equation for the hydrogen atom. Explain the significance of the three quantum numbers in the eigenfunctions of the hydrogen atom. *2+3*

(ii) State with reasons whether the following transitions for a multi-electron atom are allowed or not : *5*

1. $^3P_0 \rightarrow {}^3S_1$

2. $^1S_{1/2} \rightarrow {}^1D_{3/2}$

5. Answer any ***one*** part : *1×5=5*

(a) Sketch the binding energy/nucleon as a function of the mass number. How can it be used to explain the fission and fusion phenomena ? *3+2*

(b) With the help of a diagram, explain the working of a cyclotron. *5*

Physical Constants :

$$h = 6{\cdot}62 \times 10^{-34}\ \text{Js}$$

$$m_e = 9{\cdot}1 \times 10^{-31}\ \text{kg}$$

$$c = 3 \times 10^{8}\ \text{ms}^{-1}$$